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USE OF A PITOT-STATIC PROBE FOR DETERMINING WING SECTION DRAG  
IN FLIGHT AT MACH NUMBERS FROM 0.5 TO APPROXIMATELY 1.0

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16. Abstract  <p style="text-align: center;">The use of a pitot-static probe to determine wing section drag at speeds from Mach 0.5 to approximately 1.0 was evaluated in flight. The probe unit is described and operational problems are discussed. Typical wake profiles and wing section drag coefficients are presented. The data indicate that the pitot-static probe gave reliable results up to speeds of approximately Mach 1.0.</p>					
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# USE OF A PITOT-STATIC PROBE FOR DETERMINING WING SECTION DRAG IN FLIGHT AT MACH NUMBERS FROM 0.5 TO APPROXIMATELY 1.0

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## INTRODUCTION

The momentum method for determining wing profile drag developed in references 1 and 2 has been widely used to evaluate wing performance (refs. 3 to 12). With this method, momentum losses are determined from total and static pressure measurements made in the wake close behind a wing's trailing edge. Except as reported in references 11 and 12, the use of the momentum method has been limited to incompressible flow conditions.

This paper discusses in-flight wing section drag results determined by the momentum method and pitot-static probe measurements for a range of free-stream Mach numbers from 0.5 to approximately 1.0. The primary purpose of the report is to describe the in-flight experience using the pitot-static method at these Mach numbers. The question of the validity of the pitot-static probe wing wake survey measurements near Mach 1.0 is also addressed.

## SYMBOLS

Physical quantities in this report are given in the International System of Units (SI) and parenthetically in U.S. Customary Units. Factors relating the two systems are presented in reference 13.

$c$	wing chord at measuring station, cm (in.)
$c_d$	wing section drag coefficient
$c_{p_t} = \Delta p_t / q$	
$p$	static pressure, kN/m <sup>2</sup> (lb/ft <sup>2</sup> )

$p_t$  total pressure,  $\text{kN/m}^2$  ( $\text{lb/ft}^2$ )

$\Delta p_t = p_{t_w} - p_{t_\infty}$ ,  $\text{kN/m}^2$  ( $\text{lb/ft}^2$ )

$q$  dynamic pressure,  $\text{kN/m}^2$  ( $\text{lb/ft}^2$ )

$x$  distance of probe behind the wing trailing edge, cm (in.)

$y$  probe vertical travel at measuring plane, cm (in.)

$\alpha$  angle of attack, deg

Subscripts:

$w$  wake

$\infty$  free stream

## AIRPLANE AND TEST CONDITIONS

An F-8 fuselage fitted with a supercritical wing was used as the test vehicle (fig. 1). The wing wake measurements were made on the right wing at one span station 38.1 centimeters (15 inches) behind the wing trailing edge, or  $0.29c$  based on the local wing chord (fig. 2).

Data were obtained for free-stream Mach numbers from 0.5 to approximately 1.0 and for a dynamic pressure range from approximately  $9.6 \text{ kN/m}^2$  ( $200 \text{ lb/ft}^2$ ) to approximately  $14.4 \text{ kN/m}^2$  ( $300 \text{ lb/ft}^2$ ). Reynolds numbers based on the test chord ranged from approximately  $5.5 \times 10^6$  to  $9.2 \times 10^6$ . Angle of attack was varied at each Mach number by performing slight pushovers or wind-up turns. The turn radius was kept as constant as possible for at least 20 seconds. Altitude was adjusted to obtain the desired combination of Mach number and dynamic pressure during data runs.

## MEASURING PROBE

### Description

Figure 3 shows the probe mounted on the wing trailing edge. The fairing on the wing housed the drive unit, the transducers, and the position indicators. Figure 4 shows the entire unit and its parts. Additional information about the drive motor, position potentiometers, and fairing is presented in the appendix. Some dimensions of the probe and probe mast are shown in figure 5. The weight of the unit, including the fairing, was 1.45 kilograms (3.2 pounds). The pressure lines were approximately 76.2 centimeters (30 inches) long. The probe and probe mast

consisted primarily of stainless steel, and the mounting block was aluminum. These materials were used because of ease of fabrication and availability. Other materials could have been used.

### Operation

The pilot started probe operation during each test run. The probe rotated through a  $90^\circ$  arc, with approximately  $45^\circ$  above and  $45^\circ$  below the wing trailing edge, in approximately 15 seconds. The probe was capable of rotating  $360^\circ$  if desired. The probe could be operated in a continuous mode or in single cycles (two  $90^\circ$  arcs). Two position sensors (fig. 4(c)) were used, one to record probe position and the other to program the probe arc distance. After the pilot terminated probe operation, rotation continued until the lower position ( $45^\circ$  below the wing trailing edge) was reached.

### Mounting

The probe was mounted on a fitting on the lower surface of the right wing (fig. 3). The fitting was installed during the construction of the wing. Figure 6 shows the probe mounted on the wing with the fairing removed. The fiber glass fairing and its dimensions are shown in figure 7.

The probe was mounted so that it measured the airflow inboard of the attachment point (fig. 2). This was done to take advantage of the wing sweep to position the head of the probe as far aft of the wing trailing edge as possible. The arrangement also minimized the possibility that spanwise flow over the fairing would affect the probe measurements.

### Operational Problems

Most of the problems encountered during the flight tests were due to the design limitations of the probe unit. A major limitation was the probe's low rotational speed. With such short pressure lines and high instrument response capabilities, the probe's speed could have been increased considerably. This would have permitted wake data to be acquired at a variety of test conditions that could be maintained for only a short period of time.

Another consequence of the design limitations was the inability to define the extent of the shock losses that occurred on the upper surface of the wing at high transonic Mach numbers. This inability stemmed from the probe's small arm length and the limits of the probe's sweep angle ( $90^\circ$ ). If the arc had been extended and the arm lengthened, the extent of the shock losses could have been defined better. This limitation was understood before flight, however, so the data were interpreted by using a method that eliminated the shock losses.

## DATA REDUCTION

All the wake survey data were filtered by using a 5-hertz digital filter to eliminate large fluctuations at the higher frequencies. The data were then reduced by using the point drag method described in reference 14 to obtain the section wake drag coefficients.

The wake profiles, which included upper surface shock losses, were integrated after a fairing of the upper surface profile made its shape similar to that of the lower surface profile, deleting the shock losses. Thus, the section drag coefficients presented herein exclude shock losses.

## ACCURACY

The accuracy of the wake survey measurements made during this study relative to the free-stream conditions is presented below.

Parameter	Error in parameter, percent	Error in $c_d$ , percent
$p$	6	2
$\Delta p_t$	1	8
$y$	$\pm 3$	-

The error due to  $\Delta p_t$  was eliminated by adjusting  $\Delta p_t$  to zero outside the wake. The values above represent the maximum errors in the data in this study.

## RESULTS

The flight data presented are discussed in terms of data quality rather than wing performance.

Wake profile results are presented in figure 8 for two angles of attack at a constant Mach number. The difference in the size of the wake profiles is attributable to the partially separated flow at the higher angle of attack. The two wake profiles are well defined and clearly show the difference due to flow separation. Differences in the end conditions (at the wake edges) were occasionally found in cases where no shock losses occurred. A check of the data recorded by the airplane's air data system revealed that these differences were caused by changing flight conditions during the wake survey.

A typical wake profile that shows the effects of upper surface shock losses is presented in figure 9. Because the extent of the shock losses could not be defined,

the data were faired, omitting the shock losses (dashed line), and integrated to obtain the wing section drag.

Typical wing section drag coefficients for a range of angles of attack at a constant free-stream Mach number are presented in figure 10. These data represent integrated wake profiles similar to those in figures 8 and 9. The data at the lower angles of attack are for several flights and give an indication of the repeatability of the results. Similarly reliable results were obtained for other free-stream Mach numbers in the range from 0.5 to approximately 1.0.

### CONCLUDING REMARKS

A pitot-static probe was used at speeds from Mach 0.5 to approximately 1.0 to determine wing section drag using the momentum method. The data indicate that a pitot-static probe gives reliable results for determining wing section drag in this speed range. No major problems were encountered during this study, except that the extent of the shock losses at the high transonic speeds could not be defined because of the limited sweep and arm length of the probe.

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National Aeronautics and Space Administration  
Edwards, Calif., July 15, 1974*

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APPENDIX – CHARACTERISTICS OF PROBE MOTOR,  
POSITION POTENTIOMETER, AND FAIRING

Drive motor –

Power, V . . . . .	115
Frequency, Hz . . . . .	400
Phase . . . . .	Single
Dimensions, cm (in.):	
Width . . . . .	3.18 (1.25)
Length . . . . .	8.89 (3.5)
Speed, rpm . . . . .	10
Weight, g (lb) . . . . .	317 (0.70)

Position potentiometer (modified)\* –

Resistance, ohms . . . . .	2000
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Fairing –

Material . . . . .	Fiber glass
Dimensions (approximate), cm (in.):	
Thickness . . . . .	0.23 (0.09)
Width (maximum) . . . . .	11.43 (4.5)
Length . . . . .	44.45 (17.5)
Depth (maximum) . . . . .	4.45 (1.75)
Weight, g (lb) . . . . .	289 (0.64)

\*Only the backs and wiper elements were used.

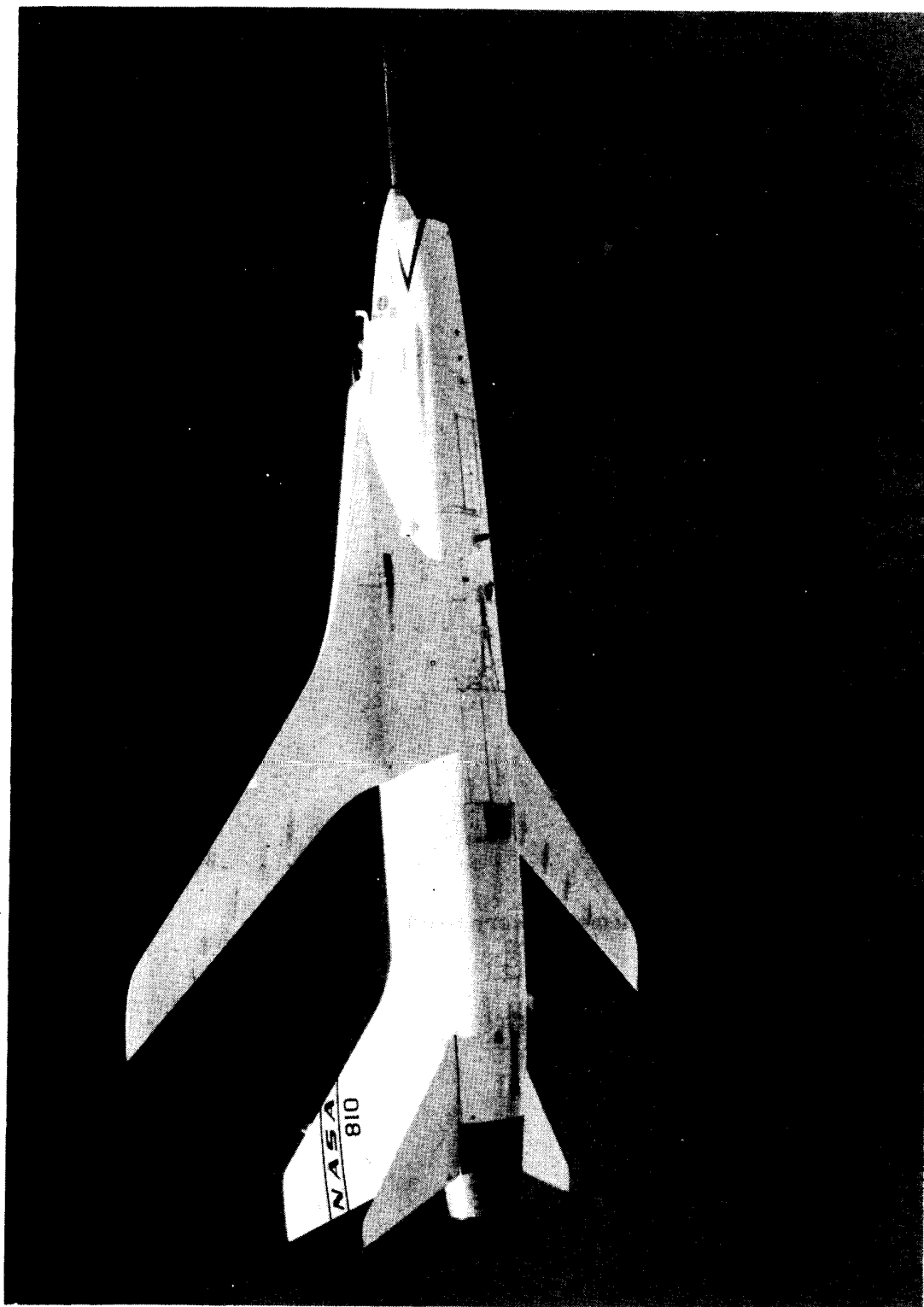


Figure 1. F-8 supercritical wing test vehicle.

E-22939

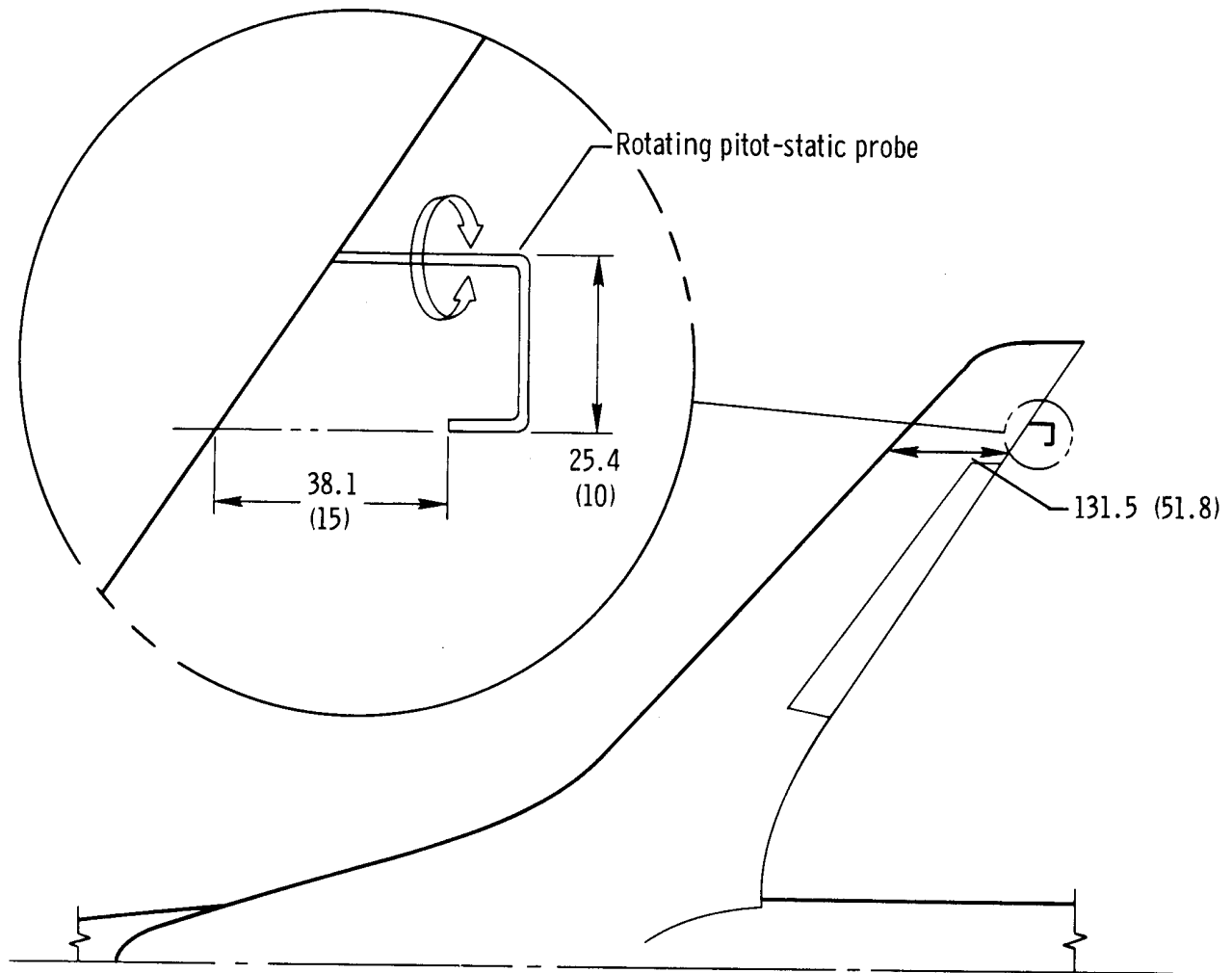


Figure 2. Location of wake survey probe. Dimensions are in centimeters (inches).

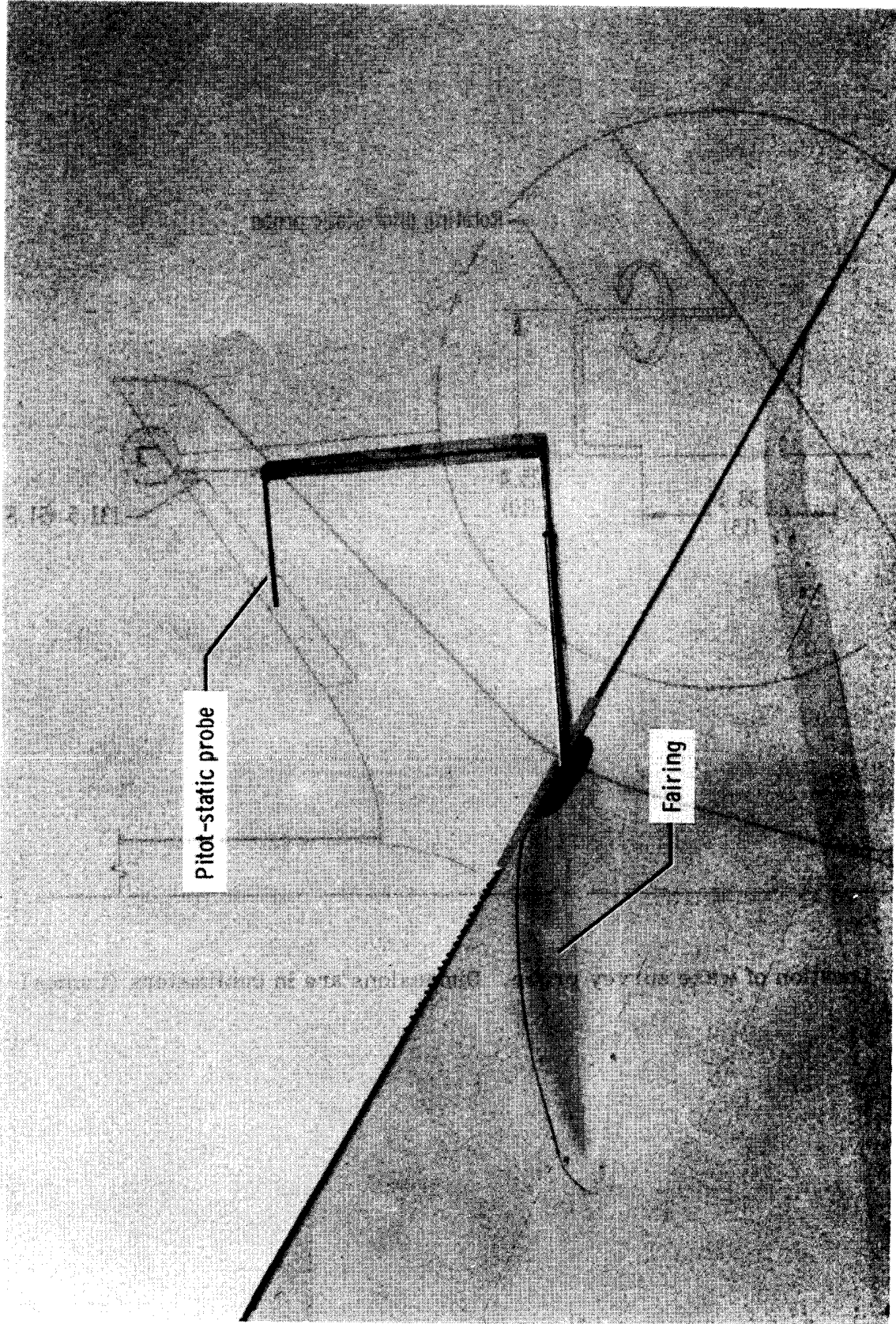
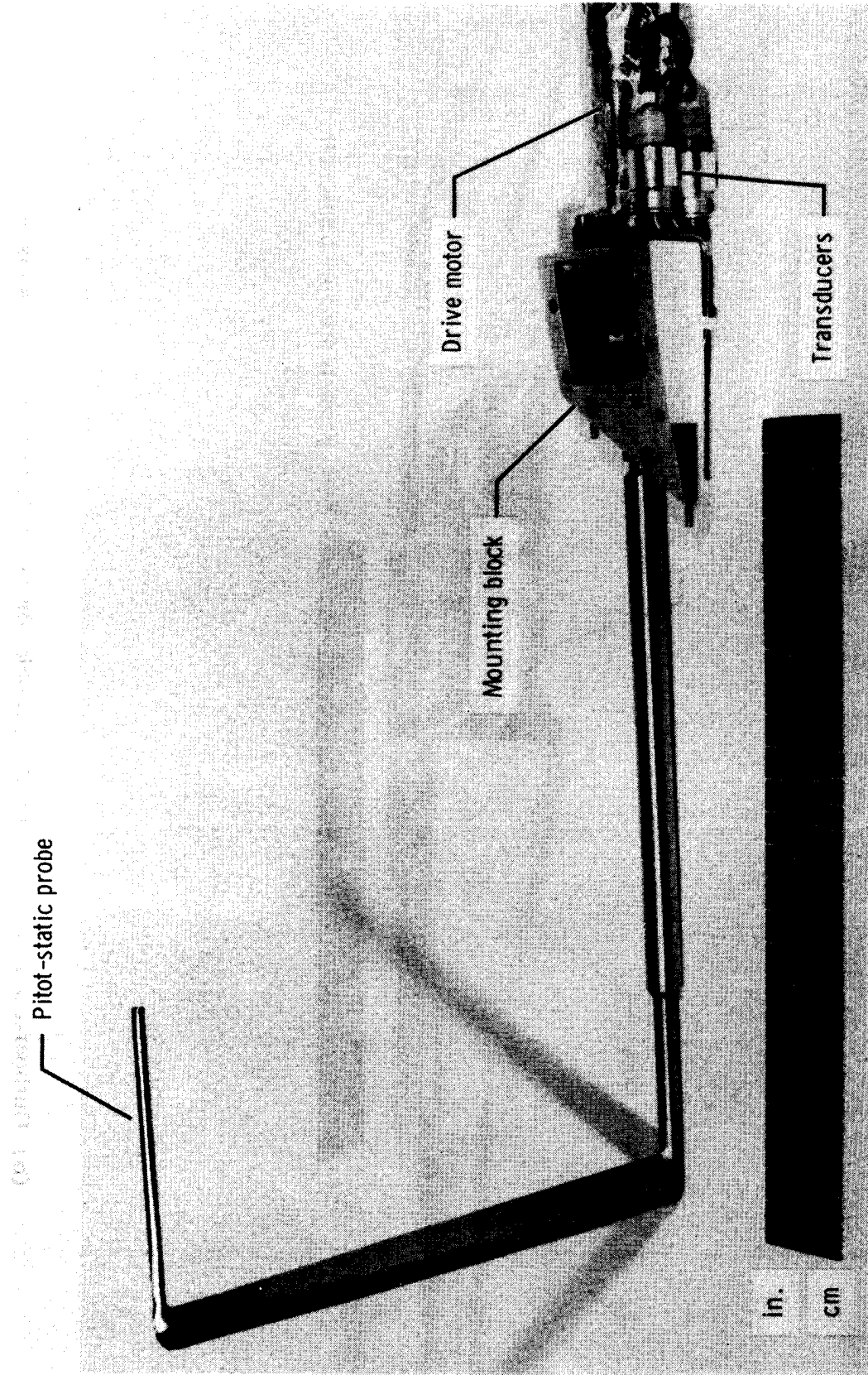


Figure 3. Lower surface of the wing showing the probe installation at the trailing edge. E-24996

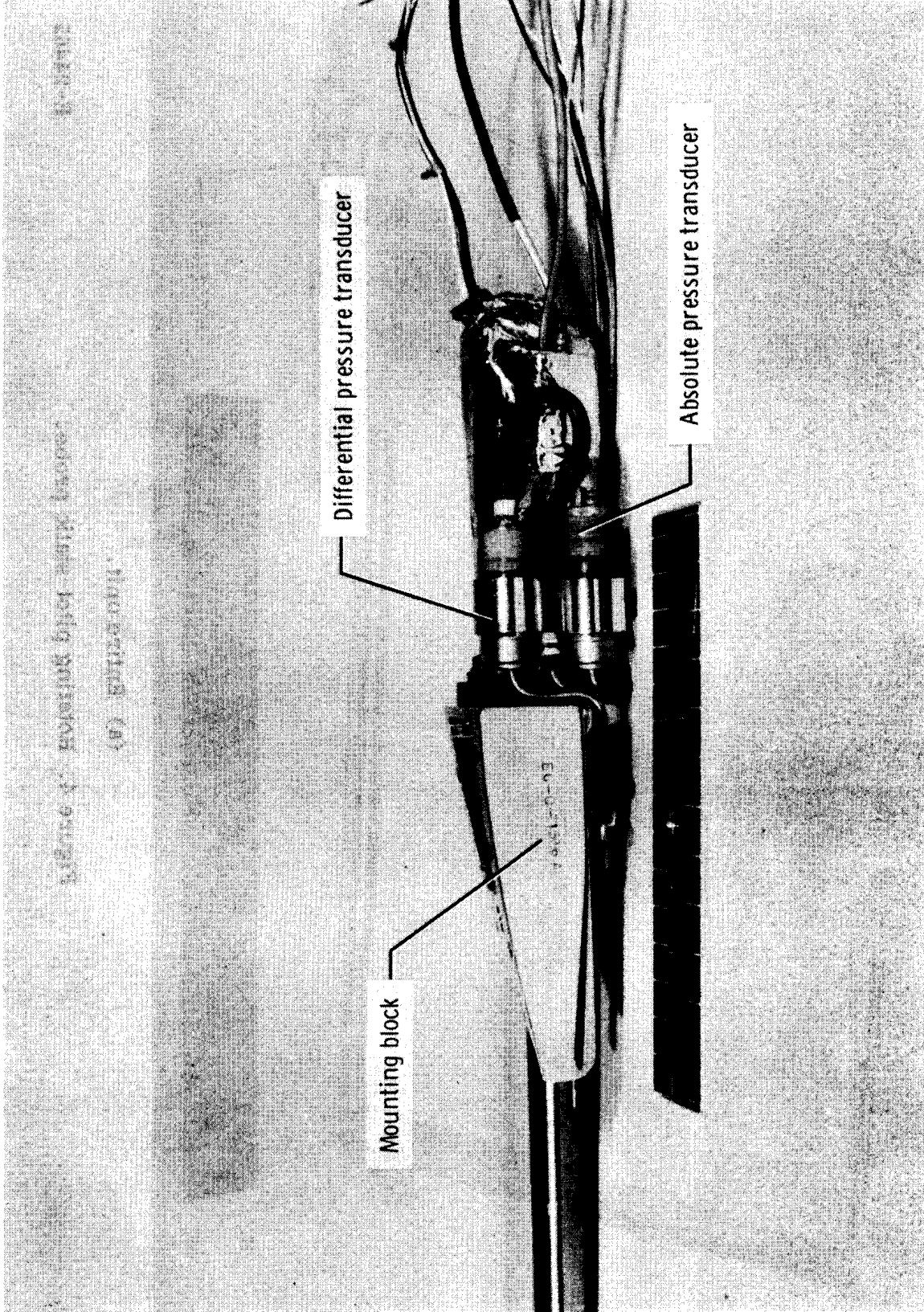


(a) Entire unit.

Figure 4. Rotating pitot-static probe.

E-24465

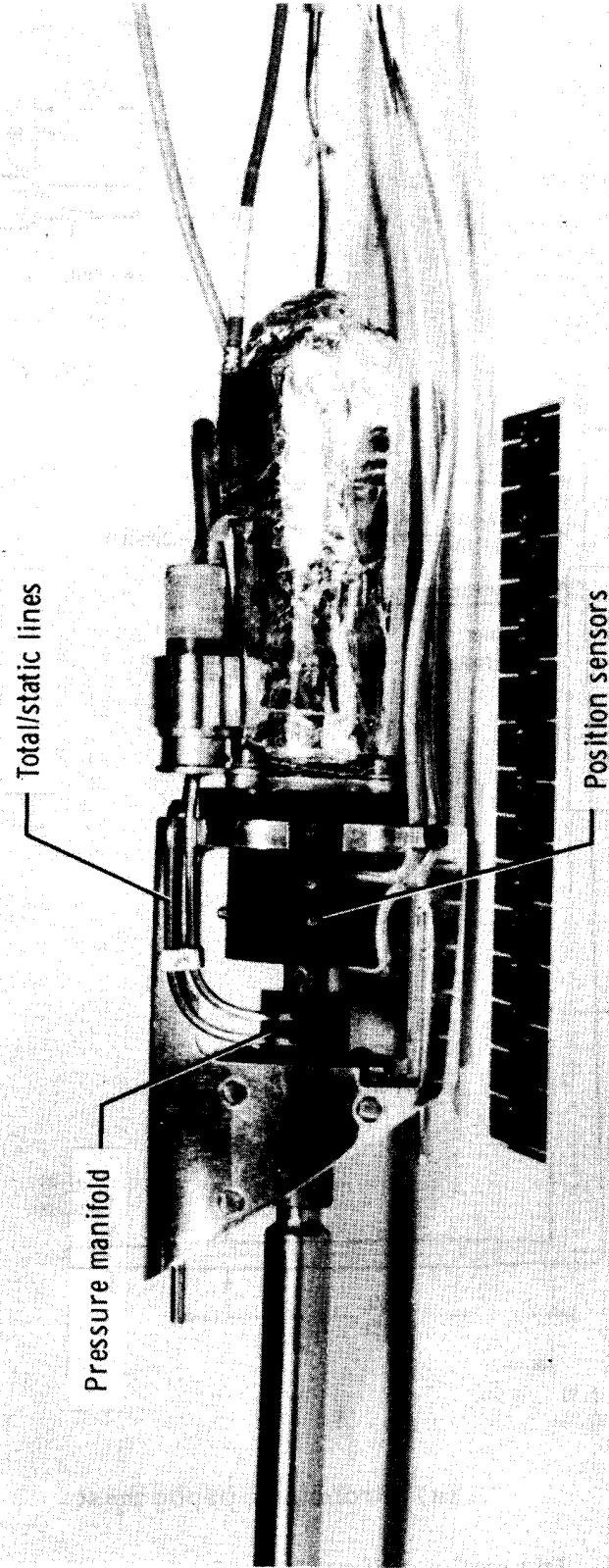




(b) Outboard side view of mounting block, drive unit, and pressure sensors .

Figure 4. Continued .

E-24462



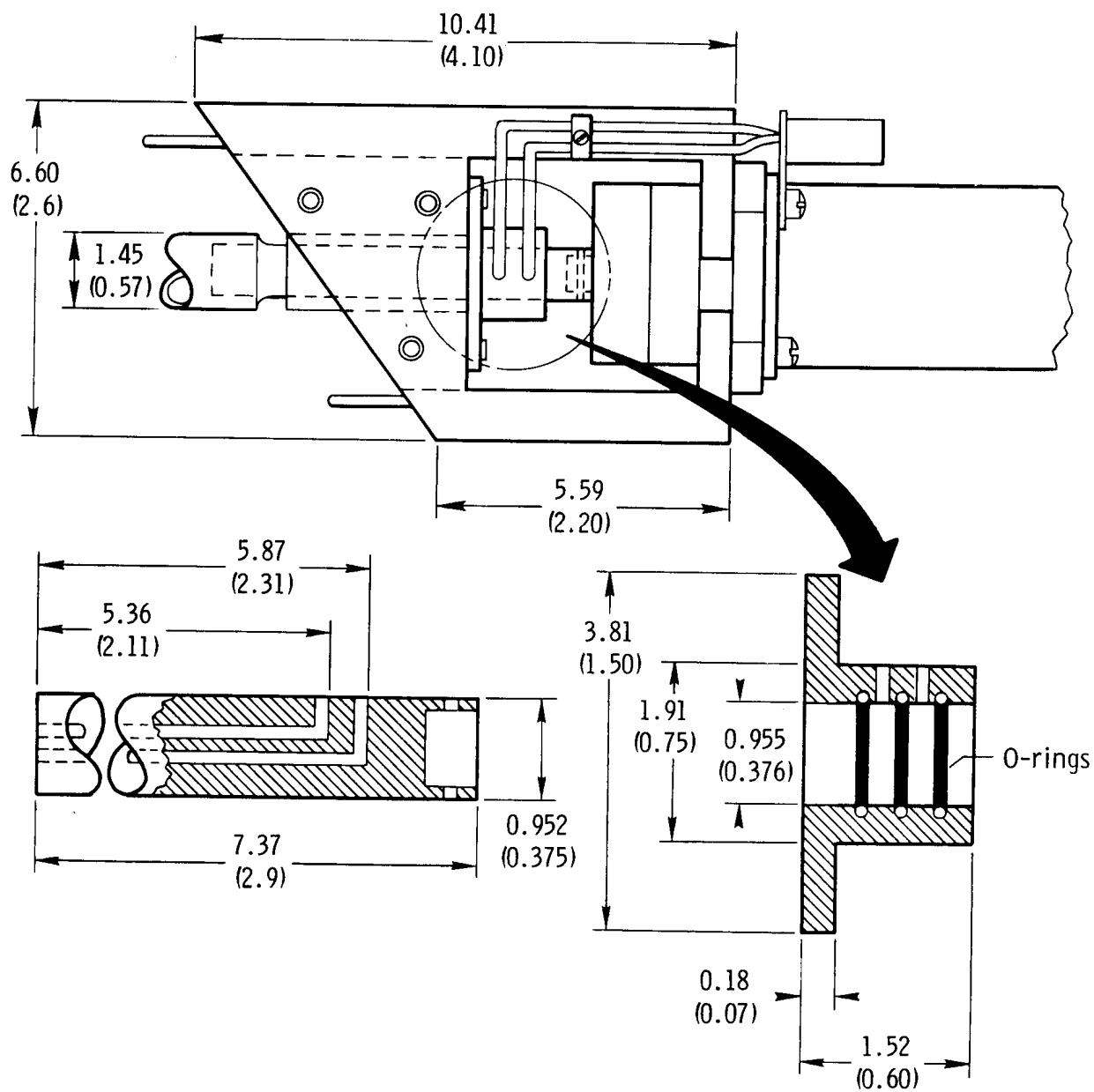
(c) Bottom view of mounting block, drive unit, and position sensors.

Figure 4. Concluded.

E-24463







(b) Mounting block, drive unit, and sensors.

Figure 5. Concluded.

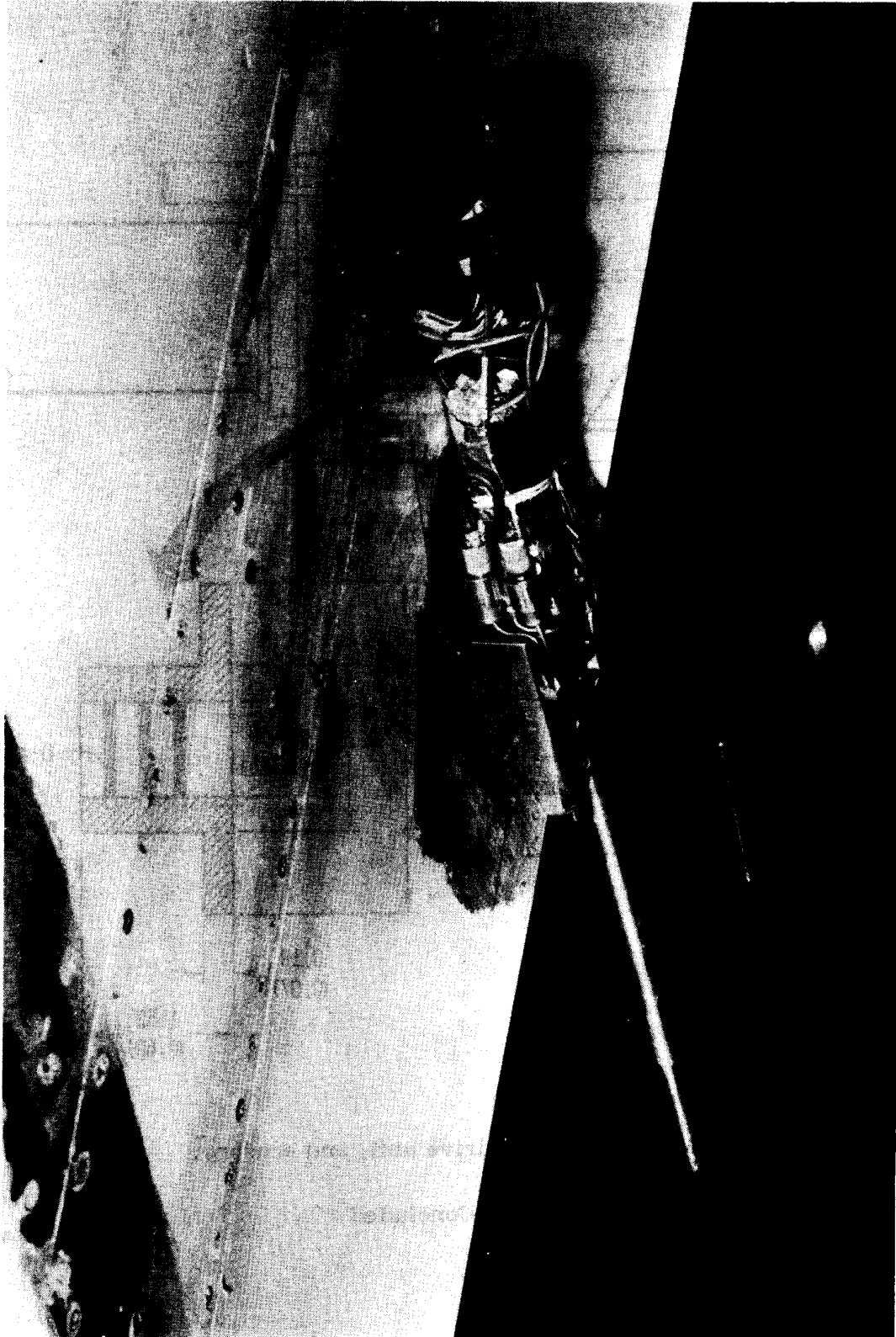


Figure 6. Pitot-static probe mounted on the wing with the fairing removed. E-24666

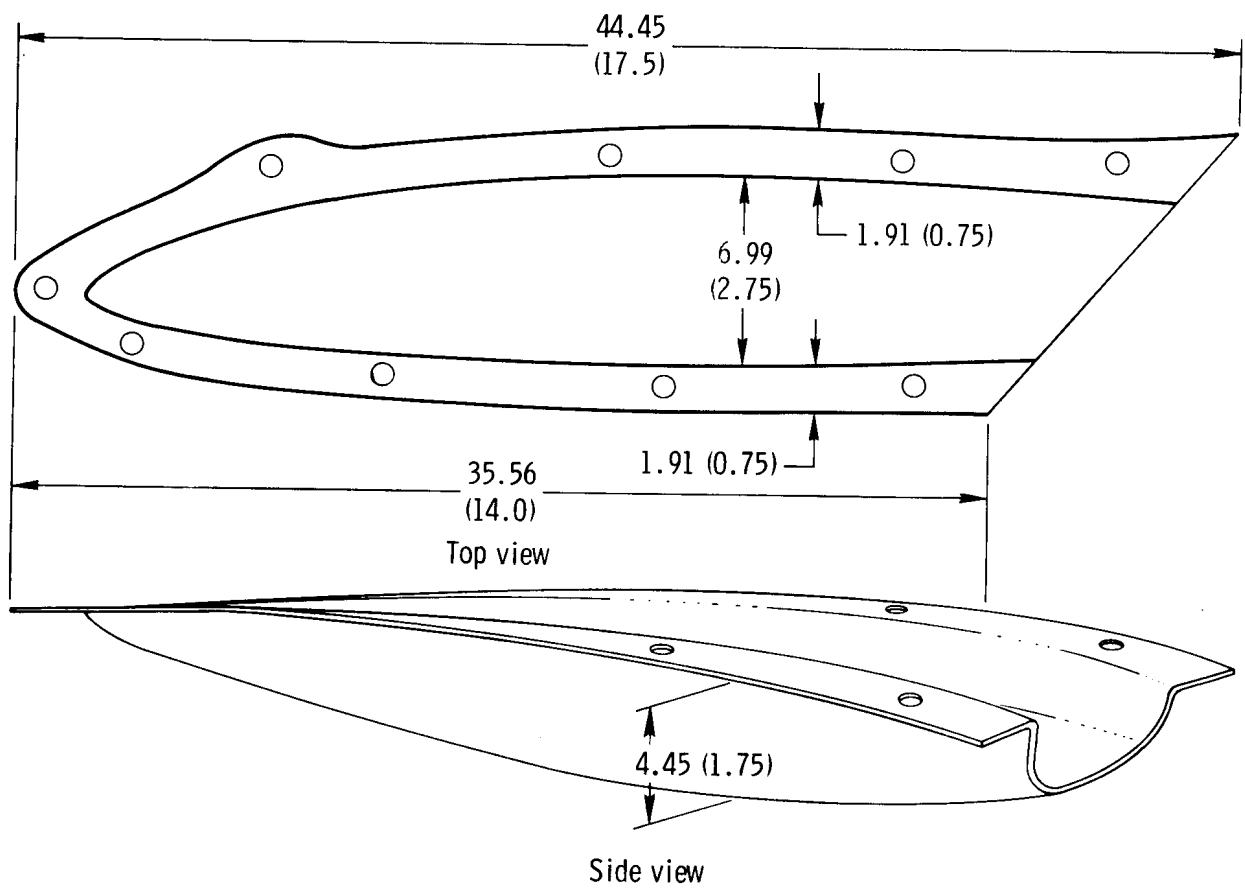


Figure 7. Fiber glass fairing. Dimensions are accurate within  $\pm 0.32$  cm ( $\pm 0.09$  in.).

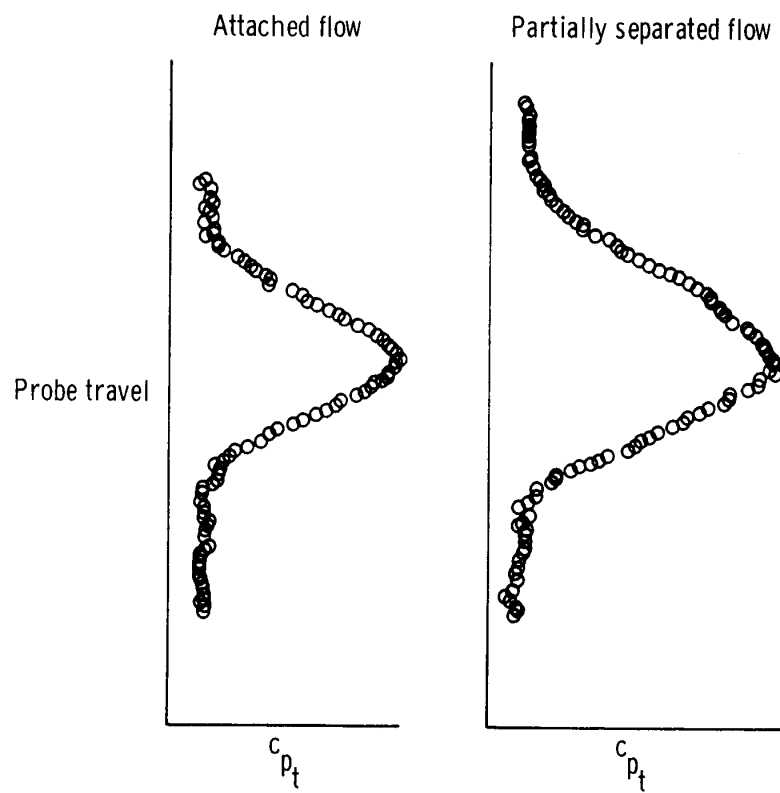


Figure 8. Typical wake profiles with attached and partially separated flow .

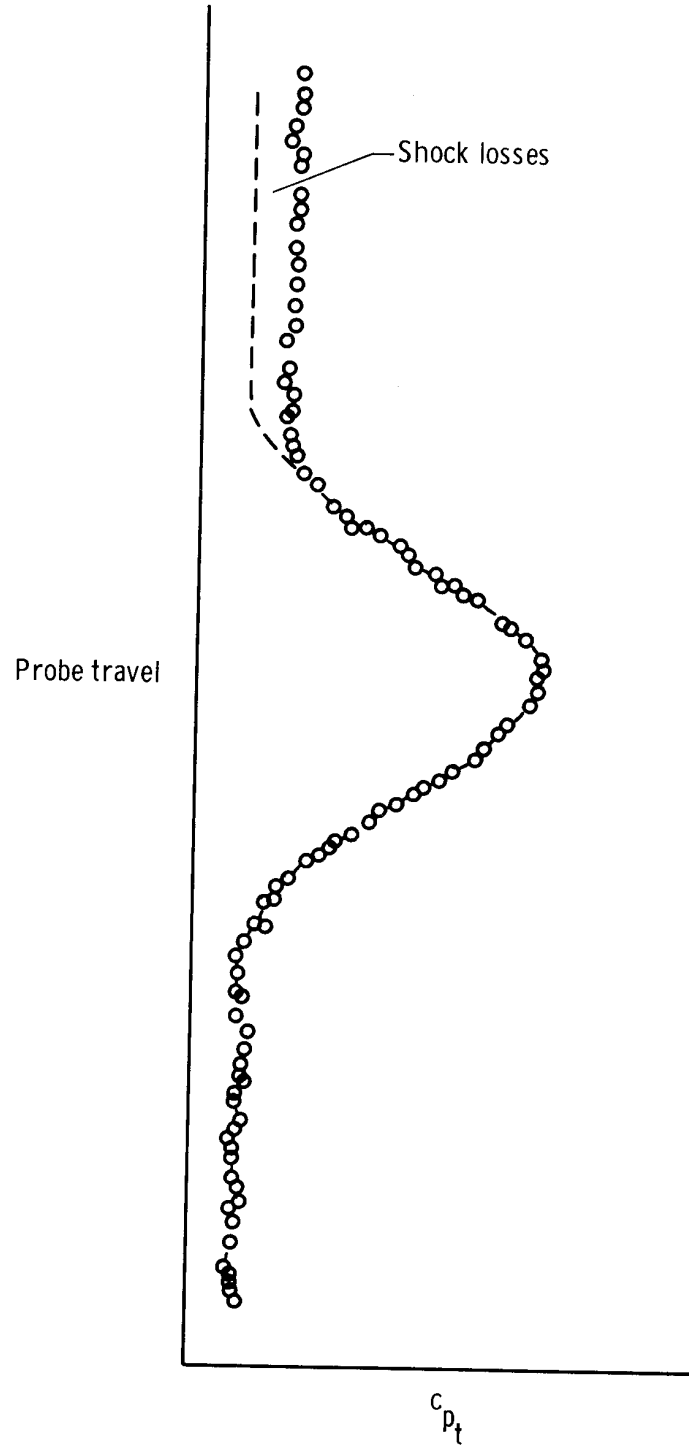


Figure 9. Typical wake profile including shock losses.

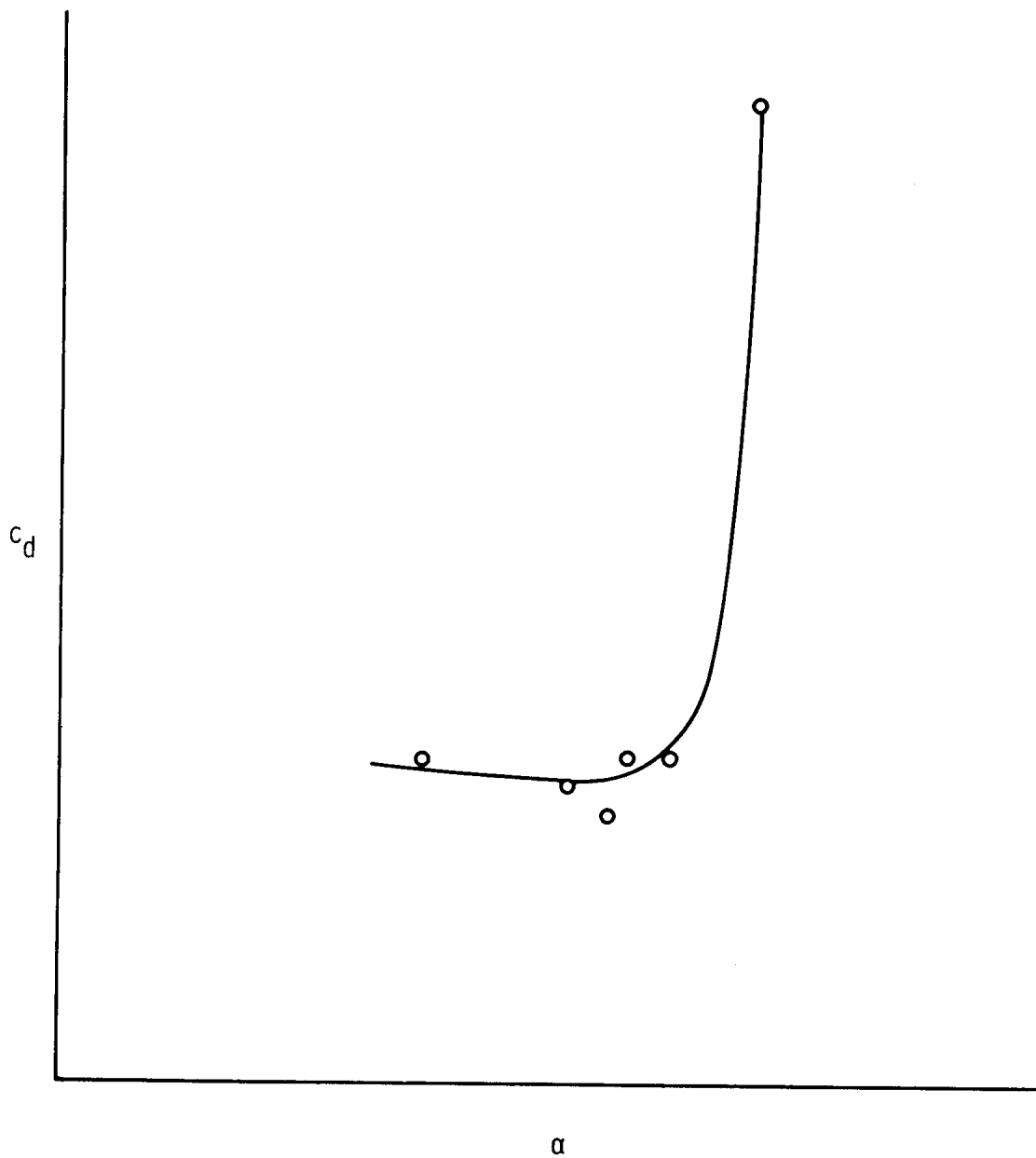


Figure 10. Typical wing section drag coefficients for a constant Mach number and varying angle of attack.